SECTION 6

NATURAL SOURCES

Emissions of ozone precursors from natural sources are included in the 2002 inventory to gain a more complete picture of emissions contributing to the formation of ground-level ozone. For Delaware, natural sources include biogenic source emissions (VOCs, NO_x, and CO) and NO_x emissions due to lightning. The wildfire category was included in the non-point section because most wildfires in Delaware are a result of human activities (i.e., untended fire, discarded cigarette butt, arson). Emissions for natural sources are reported under the following SCCs:

Table 6-1. SCCs for Natural Sources

SCC	Description 1	Description 3	Description 6	Description 8
2701000000	Natural Sources	Biogenic	Vegetation/Soils	Total
2740001000	Natural Sources	Miscellaneous	Lightning	Total

6.1 Biogenic Emissions

Biogenic source emissions result from biological activity and represent a significant portion of the natural source emissions. The biological activity of plants, especially trees, creates a significant amount of VOCs in Delaware. Microbial activity within soils is responsible for emissions of nitrogen-containing compounds, including nitrogen oxides (NO_x).

The U.S. Environmental Protection Agency developed 2002 monthly county-level biogenic emissions for the entire country (EPA, 2004) using the Biogenic Emissions Inventory System (BEIS) model, version 3.12 (EPA, 2003). EPA allowed states to accept the EPA estimates for purposes of satisfying the requirements of the Consolidated Emissions Reporting Rule (CERR). Delaware opted to accept EPA's estimate of biogenic emissions for Delaware for inclusion in the NEI. Delaware is also adopting these emissions for submission in this 2002 ozone SIP inventory. EPA's report on the estimation of biogenic emissions for 2002 is included in the supporting documentation accompanying this report.

EPA used land use data from the Biogenic Emissions Land Use Database (BELD3) as the primary activity data. Primary sources of data for BELD include the USDA Forest Service, USGS satellite data, and the Census of Agriculture from the U.S. Department of Commerce Bureau of Census. Land use is divided into four main categories: forest, urban forest, agriculture and other. Other categories consist of grassland, scrubland, rangeland, barren land, water and urban other (treated as barren).

EPA relied on 2001 meteorological data since 2002 data were not available at the time biogenic emissions were estimated.

The rate of biogenic emissions is highly dependent on the amount of biological activity, which is at its maximum in the summer and at its minimum in the winter. EPA did not calculate daily emissions for the peak ozone season. However, since EPA created monthly emission tables, AQMS calculated SSWD daily values by summing emissions for June, July and august and dividing by the number of days within the peak ozone season (92).

6.2 Lightning

Lightning is a source of nitric oxide (NO). Lightning forms NO through a high temperature reaction from the energy released during a lightning flash. Lightning can release about 10^5 Joules per meter (J/m), and produce temperatures of about 30,000 degrees Kelvin (°K). NO is in thermodynamic equilibrium with nitrogen and oxygen at temperatures above 2300°K, and as the heated air rapidly cools below 2000°K, NO becomes a steady-state species.

Activity for this category can be collected from commercial lightning detection networks, such as the National Lightning Detection Network operated by Vaisala (formerly Global Atmospherics Inc. of Tucson, AZ.) Global Atmospherics had the only national database for lightning strikes available for 2002. Since archived data is only available for a fee, AQMS has relied on an average annual lightning strike rate of one cloud-to-ground strike per km^2 per year provided by Bill Geitz of Global Atmospherics, with a network detection efficiency of 86% (Geitz, 1997). Mr. Geitz also stated that most of the strikes occur during the peak ozone season, and that using a value of 75% of the annual number of strikes would be a realistic estimate for calculating peak ozone season daily emissions. This information was used to develop 2002 emission estimates for NO_x from lightning.

When estimating NO_x emissions, the *EIIP, Volume V* (EPA, 1997) preferred method estimates NO production by assuming the frequency and type of lightning strikes, and the amount of energy released. The method derives emission estimates for cloud-to-ground (CG) flashes and intra-cloud (IC) flashes. The method relies on the following four assumptions:

1) Global production of NO by lightning is six Tg N/yr;

2) Global flash rate is 100 flashes/sec;

3) IC flashes occur approximately four times more frequently than CG flashes, a number which varies with latitude; and

4) CG flashes are approximately ten times more energetic than IC flashes.

The following emission factors have been developed based upon the above assumptions:

- CG flashes: $2.9 * 10^{26}$ molecules NO per flash; and
- IC flashes: $2.9 * 10^{25}$ molecules NO per flash.

In order to calculate emission estimates for this source, the emission factors are applied to activity for the inventory area taking into account any corrections to the activity measurements. The correction factor compensates for lightning flash detection network efficiency, including a lack of detection of IC flashes by the network.

The preferred method for estimating emissions from lightning requires the collection of activity level data on CG lightning flashes and determination of the study area’s latitude. Activity for IC flashes is calculated from the CG activity. It is assumed that IC flashes occur about four times more frequently than CG flashes, and this ratio varies with latitude.

The equation to calculate emissions from lightning is as follows:

$$L_{NO} = AREA \times \left\{ \left(N_{CG} \times (1/E_{CG}) \times EF_{CG} \right) + \left[N_{CG} \times (1/E_{CG}) \times EF_{IC} \times \left(\frac{10}{1 + \left(\frac{\theta}{30} \right)^2} - 1 \right) \right] \right\}$$

where:

L_{NO} = NO emissions for lightning flashes in study area, molecules NO
$AREA$ = Square kilometers of study area (county, including waters of DE Bay)
N_{CG} = Number of CG flashes recorded by detection network (strikes/km^2 per year)
E_{CG} = Efficiency of the detection network
EF_{CG} = Emission factor of NO for each CG lightning flash (in molecules NO/flash)
θ = Latitude of the study area in degrees
EF_{IC} = Emission factor of NO for each IC lightning flash

6.3 Results

Table 6-2. 2002 Statewide Annual and SSWD VOC, NO_x, and CO Emissions for Natural Sources

SCC	Category Description	Annual (TPY)			SSWD (TPD)		
		VOC	NO_x	CO	VOC	NO_x	CO
2701000000	Biogenic	26,580	612	2,794	173.94	2.63	16.08
2740001000	Lightning	---	151	---	---	1.23	---
27xxxxxxxx	**Total : Natural Sources**	**26,580**	**764**	**2,794**	**173.94**	**3.86**	**16.08**

6.4 References

EPA, 1997. *Emission Inventory Improvement Program, Volume V: Biogenic Sources – Preferred and Alternative Methods*, EPA-454/R-97-004e, U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, N.C., July 1997.

EPA, 2003. *Biogenic Emissions Inventory System (BEIS), Version 3.12*, a stand-alone module to the Sparse Matrix Operational Kernel Emissions (SMOKE) system, CHIEF website, November 17, 2003.

EPA, 2004. EPA-developed Biogenic Emissions for the 2002 NEI, U.S. EPA, Office of Air Quality Planning and Standards, Emission Factor and Inventory Group, Research Triangle Park, North Carolina, March 2004.

Geitz, 1997. Bill Geitz, Global Atmospherics, Inc., personal communication with John Sipple, Environmental Scientist of DNREC, Air Quality Management Section, May 2, 1997.